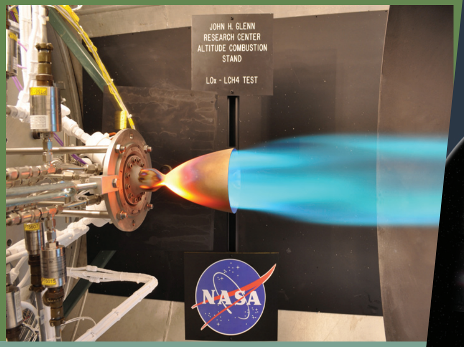
Green Propulsion Research

NASA is heavily involved with efforts to develop new sources of propellant fuel for its satellite and space exploration vehicles. These "green propellants" are not intended to put rockets and their payloads into orbit. But they are sought as alternatives to hydrazine. This fuel has long been used for powering in-flight thrusters and course correctors as part of the Phoenix and Space Shuttle Programs and many Deep Space Missions. Consisting of nitrogen and hydrogen atoms, hydrazine has been used since World War II. One of its primary benefits is that it can be stored for long periods of time.

Hydrazine is known to be a very toxic material. The U.S. Environmental Protection Agency has determined that hydrazine can cause serious health effects from even short-term exposure. As a result, NASA's use of this propellant has meant high costs associated with necessary safety procedures to protect workers and the environment. These measures include an increase in ground handling procedures that can cause a risk to mission, by increases in time and expenses associated with launches. NASA has long sought a safer, but still effective, replacement for hydrazine and is now conducting research supported by the Agency's Space Technology Program.

NASA recently contracted with Ball Aerospace & Technologies to demonstrate a green propellant alternative. Tests are planned over a three-year period in conjunction with NASA Glenn Research Center, and USAF labs at the Wright Patterson and Kirtland Air Force bases (in Ohio and New Mexico respectively). NASA expects that the Kennedy Space Center in Florida will fly what is termed the Green Propellant Infusion Mission in three years, to compare lab testing results with those of incorporation into an actual mission. ■



NASA has conducted tests of fuels to replace hydrazine at several of its facilities, including this test firing at the John H. Glenn Research Center.

This poster helps to explain NASA's commitment to find a "green propellant" as a hydrazine replacement.

Integrating Education into the Design Process

NASA is committed to educating and training its designers, engineers and project managers to integrate green engineering principles during the design phase and throughout the project life cycle. In January 2011, NASA began offering a three-day Green Engineering course originally developed and taught at Virginia Tech University. Given in conjunction with NASA's Academy of Program/Project & Engineering Leadership (APPEL) the course was a major factor in NASA receiving a GreenGov Lean Clean and Green Award from the White House Council on Environmental Quality. The course includes:

- Identifying and communicating NASA engineering challenges and opportunities regarding environmental impacts – and future risks, requirements and potential solutions
- Designing and developing materials, products, processes, hardware and systems that are inherently safe, generate less waste and use energy more efficiently
- Describing and applying basic life cycle assessment techniques for engineering new products, considering environmental and energy impacts throughout the life of the project from design through operation to its eventual disposal

Since its inception, this course has been offered at several NASA Centers, generating great interest from employees. In fact, every available seat has been filled for all sessions whenever the course is presented. This popularity bodes well for NASA's future as design and engineering personnel see value in an approach that better utilizes their input and observations. ■

Designing for Future Benefits

NASA's focus on green engineering is paying dividends. The Environmentally Responsible Aviation Project (part of the Aeronautics Research Mission Directorate) has implemented green engineering into its examination of a wide variety of alternative fuels to reduce emissions. NASA is also working with a range of lightweight materials for wings and fuselages in the next generation of more fuel-efficient aircraft. In addition, NASA's Human Exploration and Operations Mission Directorate has estimated that advances in green engineering practices implemented into human space exploration will bring additional benefits beyond accomplishing the mission. The Directorate estimates that 80% of all funds invested in green engineering support for human space exploration will benefit America's economy via "terrestrial applications" of exploration technology. Such benefits will likely include:

- Zero emission power sources (fuel cells and power cells)
- Lightweight/long-lasting battery alternatives
- Efficient and reliable distributed energy storage
- Increased electrical power generation efficiency
- Decreased fuels-related pollution from aerospace and ground vehicles
- Advanced vehicle technologies

As NASA continues to move forward on developing new air - and space - craft, green engineering will play an increasingly important role in reducing risks to the current mission, and help the Agency maintain its global leadership role in the missions of the future.

For More Information, Contact

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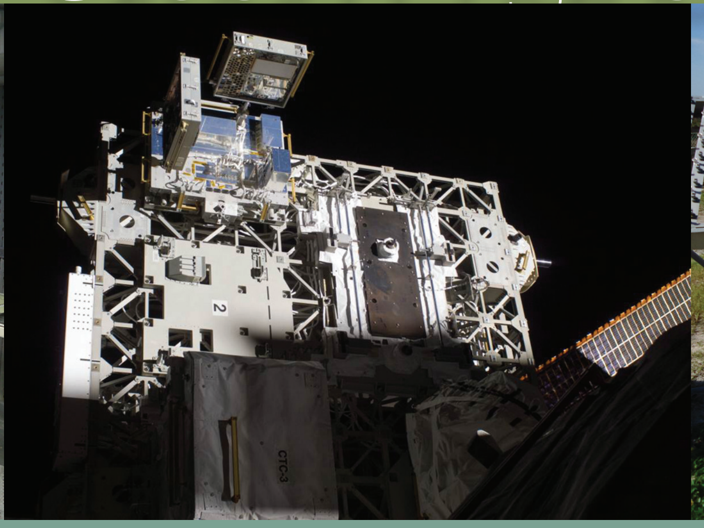
National Aeronautics and Space Administration

NASA & Green Engineering



Helping NASA Design a Successful & Sustainable Future

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Green Engineering

More than a half-century of NASA accomplishments in space are being complemented by more recent initiatives to provide for a sustainable future on Planet Earth and sustaining the exploration of the universe. Since the 1960s the Agency has developed technologies that optimize energy efficiency while recycling water, reducing water and energy use and protecting air quality. Today green engineering is helping to ensure that NASA accomplishes its mission by minimizing and mitigating risks, especially those from materials that are obsolete or restricted by national and international environmental regulations. Green engineering is also enhancing mission effectiveness and efficiency by increasing multiple uses of materials and the reuse of wastewater and air in closed systems, while reducing weight and minimizing exposure to hazardous materials on long-term missions.

NASA's goal is to promote strategic life cycle management throughout the Agency. This initiative includes processes and tools for the research and development of technology, materials, hardware, systems and new energy sources. In all these areas, NASA is undertaking advances that are inherently less costly, maintain or improve performance and are safer for the public. Green engineering also involves the design of materials, processes, systems and devices over the entire life cycle of a product or project.

GREEN ENGINEERING BENEFITS NASA IN MANY WAYS, THROUGH:

- **Improving** decision making in system development by promoting the adoption and use of green engineering methodologies within the decision making.
- **Influencing** procurement actions within the supply chain to acquire and use sustainable materials and products.
- **Inspiring**, motivating and incentivizing designers, engineers and managers by facilitating a change in NASA's culture and improving NASA policies. This change involves managers, engineers and designers, encouraging them to ask questions about where materials and products originate, how much energy they use and their eventual disposition.
- **Communicating** with and educating students and space personnel by sharing techniques, methodologies and tools.
- **Collaborating** and sharing resources with national and international partners.
- **Reducing** the use of energy, water and other resources, as well as project life cycle costs.
- **Increasing** the applicability of energy and other exploration technologies for use on earth.

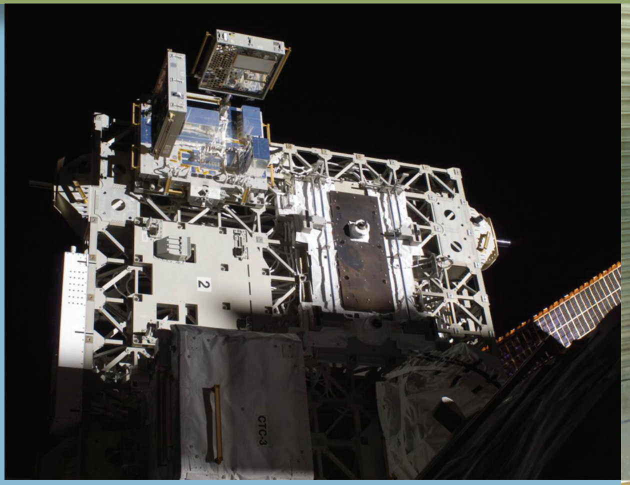
Materials Selection & Testing is Key

To mitigate risks, and improve performance and efficiencies, NASA has become heavily involved in research efforts to identify, develop, test and utilize new materials. NASA's efforts to find acceptable replacements for materials and products containing lead and hexavalent chromium are being spearheaded by the Technology Evaluation for Environmental Risk Mitigation Principal Center (TEERM).

Fifty years ago, just two nations – the United States and the former Soviet Union – engaged in satellite research and human space flight. But today, space research and exploration is truly an international pursuit. For example, the European Space Agency (ESA) has 20 member nations, as well as participation from several others in cooperative agreements. In addition, 18 ESA members are part of the 27-member European Union (EU), meaning the U.S. must operate in an increasingly international marketplace and global economy.

In recent years, European and other nations have developed strict health, safety and environmental regulations. These regulations are aimed at minimizing – and eventually eliminating – the use of materials that are now considered hazardous. These include lead and hexavalent chromium, materials contained in components and applications heavily used over the years by NASA and other aerospace industry participants. Lead, especially as part of an alloy mixed with tin (tin lead), has been used for decades in soldering the many thousands of circuit boards and other electronic components used in NASA facilities and aerospace vehicles.

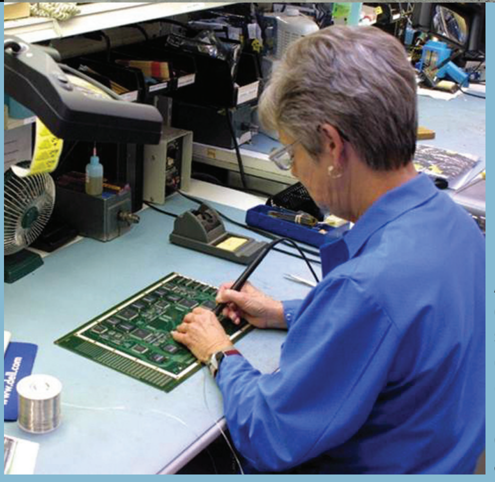
The potential for even more stringent regulations has led to a shift away from using lead in electronic components. Many U.S. electronics manufacturers have joined European and Japanese counterparts in seeking to limit and eventually phase out leaded components. This has caused shortages in the supply chain for components with tin lead finishes used in current electronics manufacturing.



NASA tested lead-free electronics assemblies in space from 2009 to 2011 on the International Space Station (ISS). During this period a components box made with lead-free solders (upper left of photo) was affixed to the ISS.

As part of NASA's Hexavalent Chromium-free Pretreatments Project, a new coating is being applied to metal test panels.

At the Kennedy Space Center's Beachfront Corrosion Center, an inspector checks the condition of these panels.



A worker conducts soldering during testing of lead-free materials on electronics assemblies.

During this period of transition, there is an increasing likelihood of manufacturers inadvertently using lead-free components in electronic assemblies that are designed and intended to contain tin lead. This constitutes a NASA mission risk since the mixing of lead and lead-free materials in electronics assemblies can cause reduced reliability and may result in a phenomenon known as "tin whiskers." The latter are crystalline structures on surfaces where tin is used as the final finish. Such whiskers can grow to several millimeters and can cause short circuits and other electronic failures.

NASA's TEERM works with other stakeholders, such as the Department of Defense (DoD), U.S. Air Force (USAF) and U.S. Navy (USN) – and aerospace industry partners. Along with a variety of national and international partners TEERM is using green engineering principles in testing several lead-free alloys. These tests involve resistance to vibration and mechanical shock as well as thermal considerations in several environments, and examine how these materials would hold up in space. NASA tested lead-free electronics assemblies in space, part of the Materials International Space Station Experiment-7 (MISSE-7) from November 2009 to May 2011. The Lead-free Technology Experiment in Space Environment (LTESE) demonstrated that lead-free electronics assemblies could be used on low-Earth orbit space flight applications if tin whisker mitigation is incorporated into the design of these electronics assemblies.

To date, some solder alloys, such as the combination of tin, silver and copper, have shown favorable results. However, these lead-free solder alloys do not perform as well as tin lead when subjected to the harsh environments testing described in the previous paragraph. Thus, green engineering must continue to play an important role in developing more lower-risk solder alloys that can function as well as their leaded predecessors.

The application of green engineering principles is also evident in the testing of several coatings that are free of hexavalent chromium. Hexavalent chromium coatings have traditionally been used by NASA for corrosion protection in applications ranging from launch structures, to the exterior of aviation and aerospace vehicles, to electronic component boxes. But both the U.S. (through the Occupational Safety and Health Administration) and European nations have placed severe restrictions on these coatings and the EU is seeking to eliminate hexavalent chromium use by 2016.

TEERM has joined ESA and EU members in seeking replacement materials to safely accomplish their missions. In 2004, NASA joined a partnership with several aerospace industry partners from Portugal to test new coatings. To date, one coating has passed three years of in-flight application without any deterioration. In addition, NASA is involved in research efforts with USAF, USN, DoD and the EU to identify and test other coatings free of hexavalent chromium on aerospace vehicles. ■